On Amphibious and Migratory Fishes of Asia.

By Francis Day, Esq., F.L.S.

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Nearly nine years since (May 14th, 1868) I laid before the Zoological Society of London the results of some investigations which I had made in Madras respecting the modes of respiration amongst Indian freshwater fishes. Since that time, although more facts have come to my notice, materials have scarcely been sufficient to enable me positively to prove the amphibious nature of some of these inhabitants of the waters of the plains of Asia.

Now, however, mainly due to the assistance I have received from several friends, more especially Dr. Hubrecht of Leyden, I think that the period has arrived when I may venture again to request attention to the facts which I have collected, in the hope that comparative anatomists who have sufficient leisure will more fully investigate the anatomical details.

The existence of fishes in Tropical Asia having amphibious manners has long been known; but that they are amphibious, in the true sense of the word, appears to be doubted by a portion, at least, of the scientific world. Professor Huxley has remarked "that there are some fishes which, besides gills, possess an apparatus for breathing air directly. This apparatus, represented by the air-bladder of ordinary fishes, first takes on its new character and becomes a lung in that remarkable genus *Ceratodus*, in which it exists as a large cellular structure situated in the upper part of the abdominal cavity just under the vertebral column, and connected with the gullet by a slit (the glottis), by means of which the fish can pass air from the mouth into the lungs. It is not, however, this peculiarity of opening into the œsophagus which constitutes a lung; for the air-bladder of many fishes possesses an open duct of a similar nature: the great distinguishing feature is, that the blood taken to this bladder does not pass into the ordinary venous channels, but is returned immediately to the heart in a purified condition by a special vein." ('Nature,' March 23, 1876, p. 411.)

The above extract would appear to advance the three following propositions:—

First. That in fishes we first perceive the swim-bladder assum-

ing the functional character of a lung in the genus *Ceratodus*, rendering it amphibious.

Secondly. That this respiratory sac, which has the functional character of a lung, is the homologue of the air-bladder or swim-bladder of ordinary fishes.

Thirdly. That the distinguishing character of an amphibious fish is that the blood is purified at a respiratory organ distinct from the gills, receiving venous but returning arterial blood into the general circulation.

I propose in the present communication adverting more particularly to the following points:—

First. That there are fishes in Asia which normally respire atmospheric air direct.

Secondly. That these fishes possess respiratory organs having a lung-like function, and which are distinct from the gills.

Thirdly. That they are essentially amphibious, as their accessory respiratory organs receive venous and return arterial blood into the general circulation without such passing through the branchiæ or gills.

Fourthly. That this accessory respiratory sac is certainly not homologous with the swim-bladder of fishes, but may be with the respiratory sac of amphibious reptiles.

Prior to discussing these points I propose briefly relating how I have been led, step by step, to these conclusions.

Ten years since, having failed in my experiment of attempting to introduce Trout by means of their ova into the waters of the Neilgherry hills in Madras, I obtained the sanction of Government to try whether fish from the plains would succeed. At first I had great difficulty in conveying them alive, when a native suggested mixing mud with the water, and in this way many Ophiocephalidæ were carried in safety up the hills.

As it appeared to me that the existence of mud in large quantities in water would tend more to the destruction than preservation of the lives of fishes, by choking the gills and impeding circulation, I was at a loss for an explanation. The native reason was that they could not beat themselves about so much, an argument which seemed hardly sufficient to explain the circumstances.

During the monsoon months, when enormous quantities of rain-water descend from the hills to the rivers of the plains, the fish are often seen dead in large numbers, due either to the water

being poisoned from the vegetation, or simply to its being fouled, preventing respiration by choking the gills. If the dead fish are examined, it will be found that poisoned water kills all kinds of fish, fouled water only those which have no accessory means of respiration, in fact all which are not amphibious.

The collector of Bustee reported, in answer to my inquiries, "The Bela Tal at Jeitpur is formed by an embankment across a low valley, and the course of a small hill-stream lies through it. During the hot weather this stream becomes almost dry, only retaining water in holes in the midst of the jungle; these holes become full of dead leaves, and with the first burst of the rains the putrid contents are swept down into the lake. The consequence, I was told on the spot, is that numbers of fish are perfectly stupified and float on the top of the water, an easy prey to any who will take them." Mr. Hobart likewise observed, "I have never heard of poisoning being used as a means to capture fish there; but I remember seeing the stream poisoned naturally. At the end of the cold season some rain had fallen and had washed the fresh leaves into the water, which turned, from this and other causes, to a dull red colour. The fish sickened and died in thousands. On the up-stream side of the arches of the bridges and traps (weirs spanning the river) you could see millions of fish eager to get down past the obstruction and escape from the poisoned water. For a hundred yards or so the river was a mass of living heads. The fish died in a day or two, and birds of prey came from all parts to devour them. The dead fish were carted off as manure."

The Tehsildar of Buldana, in the assigned districts of the Deccan, observed that "disturbing the water of a stream so as to cause it to become muddy is said sometimes to cause the fish to die." The Collector of Tanna in Bombay remarked that when the rivers become muddy at the commencement of the monsoon, fish die in large numbers, also when they become nearly dry at the close of the hot weather. In Oudh it was reported from Faizabad that fish were captured by the water being first mudded by gangs of fifty or sixty men. In fact, I saw the same thing this last year in Ireland. The water was low; some cattle went into a small pond formed by the stream above having ceased to flow, and two Trout were thus destroyed.

On the other hand, in 1866, I was riding from Mettapolliam to Wellington, and whilst crossing the Kullaar bridge, at 4.45 P.M.,

obtained a young *Ophiocephalus gachua* (an amphibious fish). I wrapped it up in a wet pocket-handkerchief and carried it up an ascent of 5000 feet, only moistening the handkerchief twice by the way. In four hours I reached my destination ; and my companion was none the worse for its journey. In Burma the fishermen are practically acquainted with the fact that some fish, as these Ophiocephalidæ, are air-breathers. When they wish to fish some of their ponds, they let out all the water they are able, when perhaps the sole visible contents are five feet of slimy mud through which their bamboo net (*gyan*) has been drawn. Though no fish are now to be seen, they are well aware that many fine ones remain ; so they take a large sail or mat and spread it over the mud. After a time this is removed ; amphibious fishes are seen stupefied, and so are easily captured, their blood having become carbonized, due to the impossibility of their obtaining access to the atmospheric air for the purpose of respiration.

The *Anabas scandens*, or Climbing Perch of India, and its smaller relatives the *Trichogasters*, are kept four or five days alive by the natives of Calcutta in earthen pots destitute of water, and from which daily requirements are supplied, the remaining fish appearing to be as lively as when first captured. The *Osphromenus olfax* is reputed to be grown and fattened in similar pots by the residents of Batavia, the water being occasionally changed.

I think the foregoing instances are sufficient to raise the probability that there may be two forms of respiration amongst Asiatic freshwater fishes :—*first*, by employing at the gills the air contained in the water ; *secondly*, by respiring air direct.

When my attention, in 1866, was first attracted to these phenomena, I was not aware that Mr. Boake had published the previous year, in the Journal of the Ceylon Branch of the Royal Asiatic Society, a paper full of interesting facts proving that certain fish in that island were, as he termed them, "air-breathers," as distinguished from the usual "water-breathers." He records how he found men and cattle moving about over rank grass growing in a certain locality, beneath which were fish inhabiting a fluid muddy substance as thick as pea-soup. These fish rose to the surface, their presence being detected by the emission of bubbles of air. They, in fact, acted as Seals and other marine Carnivora do in the Arctic regions when rising to breathe air at their blow-holes in the ice. The sod covering the Ceylon tank or muddy spot, as recorded by Mr. Boake, acted as efficiently to prevent the fish obtaining atmospheric air as does the unbroken

ice in the Polar regions. Both adopt the same plan; both have blow-holes; and it is at these places that man watches for and captures his prey.

The generality of fish, as is well known, undoubtedly respire air which is in solution in the water in which they reside, and find such sufficient for respiratory purposes, except under some peculiar circumstances, when they obtain it direct from the atmosphere.

On June 27th, last year, I accompanied Dr. Dobson to the Dublin Zoological Gardens. In one of the tanks at the aquarium were three common eels (*Anguilla vulgaris*), whose usual mode of respiration appeared to be as follows:—Opening their mouths, they took in the amount of water they required, transmitting it backwards through the gill-opening. In this course it passed the branchiæ, and thus the blood was oxygenated. One, however, appeared indisposed; for instead of taking in water like his companions, he raised his head to the surface, and each time he did so he opened his mouth and a current of bubbles was sent backwards through his gill-openings. Here were three specimens of the same species placed in identical situations, whilst they showed different modes of oxygenating their blood; the air contained in the water sufficed for two, whereas the third was obtaining it direct from the atmosphere.

In 1871, at Calcutta, I procured some living specimens of eels (*Ophichthys boro*). The gills of this fish are contained in large cavities, one on either side of the head, those on one side being divided from those on the other by an impervious septum. On watching its movements, it was seen to distend this receptacle* with air taken in at the mouth, or, if in water, to live equally well by passing this fluid through the gill-cavity. On holding its small gill-opening firmly closed, it took in air by its mouth in distinct gasps: if its mouth were closed, it struggled until it was released, as, of course, without its use it could not respire. On exposing the gills by cutting away the gill-membranes, and then placing it in water, it could be seen to slowly move its branchiæ, even when in such a situation that it could not obtain atmospheric air direct. It appeared to be able to employ for respiration air dissolved in water or air inspired directly from the atmosphere.

We see, when the water gets foul or warm in the summer, or insufficient in quantity for the contained fish, they take in air

* In fishes having small external branchial openings the cavity containing the gills is usually large; and these fish, as a general rule, live some time after their removal from water.

direct, which is said by some naturalists to be ejected *per anum* after it has been used. Native fishermen assert that the midday is the best time to net tanks, as the fishes are nearer the surface.

In order to prove the correctness or the reverse of Indian fresh-water fishes having two normal modes of respiration, I instituted a number of experiments, which I do not propose detailing in full (see ' Proc. Zool. Soc.' *l. c.*), but some of which I must advert to for the purpose of illustrating my views.

Before, however, I commence this, I think the following proposition will be admitted—*that if fish aerate their respiratory organs from air contained in the water in which they reside, there cannot normally be any necessity for their rising to the surface to take in atmospheric air direct.*

Of course, under certain abnormal conditions, all species rise to the surface, as I have already pointed out; but the following experiment will show that the freshwater fishes of India are divisible into two distinct classes as regards respiration.

I took a glass globe which I nearly filled with fresh water and into which I put a Barbel (*Barbus*) and a Walking fish (*Ophiocephalus*): the first used its gills freely, but did not come to the surface. The second moved its gills sluggishly, but every now and then ascended to the surface; and each time it did so, it appeared to blow out a bubble of air. These were normal conditions of respiration as invariably observed in these examples of the two classes under ordinary circumstances.

I then took a piece of net, which, by means of a ring of split rattan, could be pushed into the globe of water, thus dividing the interior as by a diaphragm. This I inserted about 2 inches below the level of the water, so that it became impossible for the contained fishes to rise to the surface and obtain atmospheric air.

The result in all instances was similar. The fishes which moved their gills rapidly and did not normally rise to the surface remained unaffected; those which normally rose to the surface became more and more sluggish, and died in a longer or shorter period, apparently in a ratio corresponding with whether they had been quiescent or excited, the quiescent ones living the longest.

Conclusive as the above results appeared to be, I tried another series of experiments. I stitched a bandage round the gill-openings of both these classes of fishes. Those which normally used their gills rapidly and did not rise to the surface soon died; those

which normally rose to the surface, apparently for the purpose of respiring atmospheric air direct, were unaffected.

If, as has been and still is maintained, these accessory organs or sacs are for the purpose of retaining water to moisten the gills* whilst these fishes are wandering on the land, how comes it that when placed in a situation where such a requirement is not needed (as in a globe of water under a net) they die? On the other hand, I have kept these fishes hours, have seen them kept alive days, with merely the addition of a sprinkling now and then of water. In this moist condition they are lively, and the earthen pot in which they are contained has numerous mucus-covered bubbles present and more being constantly formed by the respiration of these fishes.

From the foregoing I came to the conclusion:—*first*, that in the fishes which died when deprived of direct access to atmospheric air death was not occasioned by any deleterious properties either in the water or apparatus employed, but simply because they were unable to sufficiently decarbonize their blood on the air present solely in the water; *secondly*, that they were able to live in moisture (out of water) for lengthened periods; *lastly*, that the cavity or receptacle admitted to exist in such fishes (as are here termed amphibious) is not for the purpose of retaining water for moistening the gills, but that its walls have a highly vascular covering, and air is passed there for the purpose of respiration, whilst it seems probable that the air, having been so employed, is ejected by the mouth and not swallowed.

I had intended forming an artificial opening through the muscles of the back into the respiratory air-sac of the *Saccobranchus fossilis*; but injuries caused by its pectoral spine assume such a phlegmonous character that I desisted, after one of my native servants had nearly lost his arm from a wound inflicted by one of those fishes, which the fishermen had previously refused to handle.

However, in looking over a paper by Dr. Taylor ('Gleanings in Science,' 1830, p. 170), I found the following observations respecting this fish:—"If a quill, open at both ends, be introduced through an incision at the side of the spine into one of these canals (air-sacs), bubbles of air will arise from it"—thus showing that this cavity is for the reception of air, not of water. Likewise, amongst the Ophiocephalidæ, if they are held firmly under water, then turned over on their backs and the gills opened, bubbles of air arise.

* If the branchiæ become dry, respiration is precluded.

Thus far it is evident that we have fishes which breathe air, die if they cannot obtain direct access to it, and whose respiratory cavities are found to contain gaseous substances, not water—or proving my first proposition, that *there are fishes in Asia which normally respire atmospheric air direct.* It now becomes necessary to inquire what are these fishes? and how do they differ in their circulation from what obtains in ordinary fish?

The genera of fishes (excluding Clupeidæ) which exist in the fresh waters of India and possess respiratory organs having a lung-like function, and which are distinct from the gills, are as follows:—

Amongst the Acanthopterygians we have genera of the Labyrinthici, all of which possess a cavity above the upper portion of the first branchial arch, which contains an elaborate apparatus consisting of thin laminæ of bone covered by a vascular mucous membrane. Of these we have species of *Anabas*, *Polyacanthus*, *Osphromenus*, *Trichogaster*. The Ophiocephalidæ have likewise a cavity above and accessory to the true gill-cavity, and covered with an extremely vascular mucous membrane. Amongst the Siluridæ, all of which possess an air-vessel in the abdomen connected by a duct with the pharynx, we have in addition an accessory air-breathing apparatus. The genus *Clarias* has a dendritic accessory branchial apparatus attached to the convex surface of the second, third, and fourth branchial arches; and this is received into a recess behind the situation of the normal gill-cavity; it appears like sticks of red coral. From the dissections of M. Geoffroy in the Nile species it would appear that these arborescent-looking organizations are composed of a semitransparent substance, their external surface being densely covered by minute branches of the branchial artery; and here some at least of the blood appears to be aerated. Cuvier assigns to this organ the double function, of affording a surface for the oxygenation of blood, and as so many hearts for propelling it into the aorta. Mr. Boake (Journal Ceylon Branch Royal Asiatic Soc. 1865–66, p. 133) shows that this genus of fishes is one which takes in air direct. The genus *Saccobranchus* has an accessory respiratory sac to the gills, which extends backwards along either side of the neural spines amongst the dorsal muscles of the abdominal and part of the caudal regions.

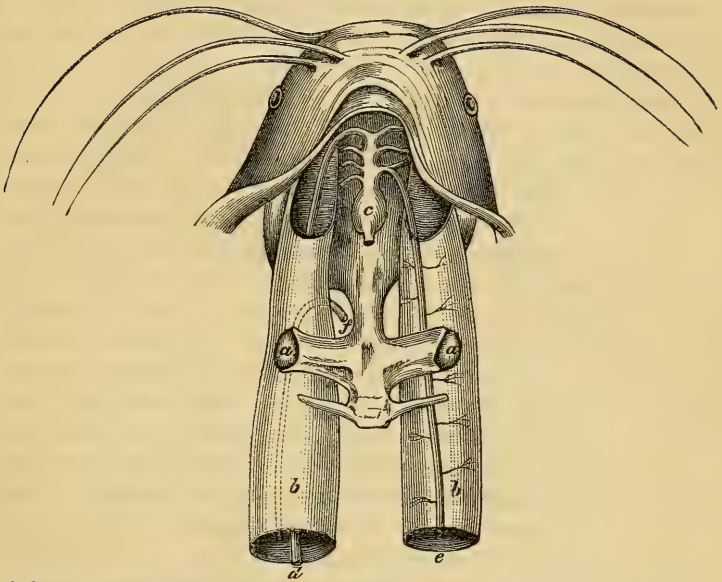
Amongst the eel-like forms of the family Symbranchidæ, we have the Cuchia eel (*Amphipnous cuchia*), which possesses three branchial arches having rudimentary laminæ and a respiratory air-sac, which communicates with the gill-cavity.

In every fish of the fresh waters of India that I have personally observed respiring atmospheric air direct, or of which I have been able to collect indisputable evidence that they do so, we find an accessory respiratory organ to the gills:—in *Clarias* an arborescent vascular one; amongst Ophiocephalidæ a somewhat simple cavity above the gill-opening also covered with a vascular membrane; in the Labyrinthici an elaborate one of thin bony laminæ. In *Amphipnous* we see that "of all the arches the second alone possesses laminæ for the purposes of breathing; and these consist merely of a few long fibrils attached to the middle of the arch and occupying but a very small extent of its surface; the third supports in the place of laminæ a thick and semitransparent tissue, which in large individuals of the species presents a fringed or denticulated appearance at its edge; whilst the third and fourth are bare, having only the membrane that fills up the space between the arches reflected over them. The principal organs of respiration are two small bladders, which the animal has the power of filling with air, immediately derived from the atmosphere. They are placed behind the head, one on each side of the neck, above the superior or vertebral extremities of the branchial arches, and are covered over by the common integuments, presenting externally, when distended with air, two protuberances of a round shape . . . . . They present, when separated from their surrounding attachments and inflated with air, thin, semitransparent, membranous parietes, resembling the posterior portions of the lungs of a serpent . . . . . Of the whole volume of blood contained in the branchial artery, one third passes through the gills and respiratory bladder, whilst the other two thirds are conveyed directly from the heart to the aorta without being exposed to the action of the air."—Taylor, *l. c.*

I asked Dr. Hubrecht to be so good as to dissect a *Saccobranchus* for the purpose of tracing out its circulation. This he did, remarking, however, that Hyrtl (Sitz. d. k. Akad. Wiss. Math. Cl. Bd. xi. Heft 2, 1853, p. 305) had already accomplished this, and that his present dissection went, as a whole, entirely to corroborate what Hyrtl had published. From the exceedingly developed *bulbus arteriosus* (*c*) of the heart spring the four pairs of branchial arteries. Of these the fourth pair on the left and the first pair on the right* are more developed than their neighbours;

* This distribution appears to be an exaggerated form of how the pseudobranchiæ are supplied with blood,

and after traversing their corresponding branchial arch, they take their way to the dorsal respiratory air-sacs (*b*), on the surface of which numerous lateral branches spring from the principal longitudinal vessel. This vessel at the respiratory sac is along the



A dissection showing the air-sacs and circulatory apparatus in *Saccobranchus*, altered after Hyrtl.

a a, air-bladder; *b b*, respiratory air-sacs; *c*, bulbus arteriosus; *d*, vessel of right side, from anterior branchial pair; *e*, vessel of left side, from fourth branchial pair; *f*, vena arteriosa, communicating with branchial vein of fourth pair of branchiæ.

dorsal surface (*d*) of the right side, and on the ventral surface (*e*) of the left; and each of them gives off a branch to the posterior wall of the branchial cavity, the mucous surface of which is provided with a network of respiratory capillaries.

The blood having passed through the capillaries of the respiratory air-sac, is collected into a *vena arteriosa* (*f*), which communicates with the branchial vein of the fourth pair of branchiæ, and the blood is driven, together with that returning from the other branchiæ, to the common aorta.

Some independent branches, going to muscles of the back &c., spring from the *vena arteriosa* of the respiratory air-sac even before its contents have entered into the general circulation by the more

regular way of the aorta, some smaller veins coming from the trunk likewise to enter into the capillary system of the respiratory air-sac.

The respiratory air-sacs are direct continuations of the mucous membrane of the branchial cavity. Two layers enter into the composition of their walls—an external fibrous, and an internal delicate one.

Here we see much the same process carried out as in the Cuchia eel—blood oxygenated at a respiratory sac, and, conjoined with that oxygenated at the lungs, returned purified direct to the aorta; whilst an air-bladder (*a*) with its pneumatic duct likewise exists.

Knowing this, we can now account in a most satisfactory manner for the experiments and their results. In these amphibious fishes the great proportion of the blood which is oxygenated is thus purified at the respiratory air-sac; this now arterialized blood, joined with the smaller portion which has been oxygenated at the gills, enters the aorta. In active life and continued muscular movement it is necessary that a large amount of blood should be decarbonized; in fact the use of the respiratory air-sacs is required, the access to atmospheric air a necessity. Failing access to atmospheric air, the gills come into play; and they are able to carry on a moderate amount of oxygenation, but insufficient for much muscular action or active exertion.

Now the problem arises, Where are amphibious fishes found? why should they exist?

The Labyrinthici are spread throughout Sind, India, Ceylon, Burma, Siam, the Malay archipelago to the Philippines, and China. Two genera are likewise found in Southern Africa. In fact they are distinctly tropical forms, and mostly found in low-lying localities but little removed from tidal reach, or in the deltas of large rivers.

The Ophiocephalidæ are distributed thoughout the plains of India, Ceylon, Burma, Siam, the Malay archipelago to the Philippines, and China: one species extends westward to Beloochistan and Afghanistan; and I have taken it at the Andamans. These fishes are very carnivorous; and I have seen them pursuing the little *Haplochili* up small streams where there would not be sufficient water to oxygenate their gills; but respiring atmospheric air, this necessity becomes avoided. The favourite resort of the Ophiocephalidæ is amongst the grass at the margin of a tank, where they can lie in such shallow water that their mouth is either

just out of, or immediately under, the surface. Here they respire with ease, and are ready to capture any incautious frog that passes that way.

It is the same with the amphibious Siluroids. It has appeared to me that they are mostly found in irrigated fields, ditches, and the like, that they push up these to deposit their ova, and are thus constantly running the risk of having the water-supply cut off. This possibility of respiring air permits amphibious fishes to ascend small streams and deposit their ova in situations where the young may be hatched and remain in safety until large enough to take care of themselves, but where their great enemies, especially carp, are unable to attack them.

We now arrive at the consideration of my fourth proposition —*that the respiratory sac is certainly not homologous with the swim-bladder of fishes, but is more probably with the respiratory sac of amphibious reptiles.*

Cuvier observed that "the gills are the lungs of animals absolutely aquatic." Geoffroy St.-Hilaire regarded the branchial arches of fishes as the modified tracheal rings of the air-breathing classes. If this view is correct, these respiratory sacs, which are merely formed by a continuation of the mucous membrane lining the branchial cavity, are a part and portion or an addition to the branchiæ.

Professor Owen denies the homology of branchial apparatus with the lungs, and tests his opinion by considering the homologies of the air- or swim-bladder in fishes. First pointing out that the totality of the organization of *Lepidosiren* is ichthyic, he contrasts it with the Ganoid *Polypterus*. The *Lepidosiren* has a cellular lung formed by the partition of the bladder into two elongated sacs, with a supply of venous blood from a true pulmonary artery, and also a pneumatic duct going to the ventral surface of the œsophagus. In the two forms compared, the arteries of the swim-bladders are derived from the returning dorsal portions of the branchial vascular arches before their union to form the aorta, venous in *Lepidosiren*, partially arterialized in *Polypterus*.

Without doubt this negative argument is good, and might be considered conclusive, were it not that we have in *Saccobranchus* a respiratory sac (*b, b*) and *also a swim-bladder* (*a*). This swim-bladder, although partially enclosed in bone, has its pneumatic duct leading into the alimentary canal. This duct, of which so much has been made as establishing a communication with the ventral

surface of the pharynx, is seen in the amphibious *Lepidosiren*; but it seems to have been overlooked that the respiratory sac of *Saccobranchus* is likewise connected with the commencement of the alimentary canal and at its dorsal surface.

The air-bladder, or swim-bladder, is found amongst the fresh-water fishes of India in two distinct forms—(1) enclosed in a bony case formed by a portion of the first or second vertebra or auditory ossicles, (2) free in the abdominal cavity. There are intermediate forms; and (3) it may even be absent. In the Physostomi, as in the Siluroids and Carps, whether enclosed in bone or free in the abdominal cavity, it possesses a duct opening into the alimentary canal. Much stress has also been laid upon the interior of this swim-bladder being occasionally found subdivided, as in the respiratory sacs of reptiles; but the same has been observed in the respiratory air-sac of the Cuchia eel.

The pneumatic duct, as already observed, has been looked upon as the homologue of the trachea, permitting in the embryo an extension of the mucous membrane lining the alimentary canal to the swim-bladder. There are some objections to this view. The pneumatic duct, it must be admitted, does open into the alimentary canal at a spot situated somewhere between the end of the stomach (as in the herring) and the pharynx. But in the majority of Teleostean fishes which possess swim-bladders, more especially in the marine forms (excluding Clupeidæ), there is no pneumatic duct and no connexion between the swim-bladder and alimentary canal; in many there is no swim-bladder at all, the same as in most fishes there is no respiratory sac.

I do not propose in this place to inquire into what is the homologue of the swim-bladder, as I hope to do so at some future date; but I will merely point out that in the carp, although it possesses a pneumatic duct leading from the swim-bladder into the alimentary canal, it has also a communication with the acoustic apparatus; in fact, such in many fishes is effected either by a tubular prolongation or by chains of ossicles, termed by Weber the malleus, incus, and stapes, in which Owen observed he had mistaken a relation of analogy for one of homology.

Lastly, I would observe that the artery to the swim-bladder carries arterial blood from the abdominal aorta, cœliac artery, or branchial vein, whereas that to the lungs or respiratory air-sacs conveys venous but returns arterial blood.

In the genera *Saccobranchus* and *Clarias* we find a swim-

bladder as described, with its pneumatic duct leading to the alimentary canal—and its supply of blood being arterial when received, venous as returned into the general circulation. But we have also the respiratory air-sacs, which are direct continuations of the mucous membrane of the branchial cavity, and consequently in the embryonic state were connected with the upper extremity of the alimentary canal. That this respiratory air-sac with a lung-like formation is, as a rule, absent in fishes, is no argument against this view; for the swim-bladder is likewise often absent. This respiratory air-sac, when existing, appears to be always in connexion with the alimentary canal, the swim-bladder only sometimes, whilst the latter has also communication with the acoustic apparatus. Lastly this respiratory air-sac receives venous and returns arterial blood into the general circulation.

The *Saccobranchus*, in short, is a true amphibious fish, with both a respiratory sac and swim-bladder, the former of which has an analogous function with, and is, I believe, the homologue of, the respiratory sac of amphibians; whereas its swim-bladder, which cannot also be the homologue of the same organ, both existing in the same species, I leave for future consideration.

Having thus briefly reviewed the amphibious fishes of India and the East, we arrive at the question of the migrations of Indian fishes. Before commencing this, a few explanatory remarks are necessary. Thus marine fish very frequently migrate into the fresh waters for breeding or predaceous purposes. Sometimes passing over high banks with a flood tide, their return to the sea is frustrated by the waters falling; and it not uncommonly happens that fish thus made prisoners of cannot reenter the sea until the succeeding year. Many doubtless die; some do not; in fact, Hyder in the last century introduced the *Chanos salmoneus* from the sea into a tank in Canara, and they are there to this day. On the other hand, did one ever hear of a freshwater fish retiring to the ocean to breed? one has been said to have been captured out at sea. I allude to the *Gobius giuris*. I do not question the fact; but I suppose the reason to have been as follows. During the monsoon-season great volumes of water are carried down the rivers, dry watercourses become impetuous torrents, rivers are so full that nothing withstands their current. I have seen hill-snakes washed down in Malabar, even so far as Cochin; and at one of these periods I obtained a bottle of fresh water taken some miles out at sea, but opposite the opening of the Cochin river.

Freshwater fishes, so far as I know, cannot live in the sea; it is entirely unsuited for them; and this is one reason for believing that as Indian freshwater fishes are found in Ceylon, the Andamans, and Nicobars, there must have been at one time a land connexion, so that a freshwater continuity was possible.

Limiting my remarks to the migrations of strictly freshwater fishes in India, I think there are two subjects for consideration:—

(1) Migrations as observed at monsoon-seasons.

(2) Fishes falling from the clouds.

The migrations of fishes at the commencement of monsoons are due to two causes—breeding-purposes, and a search for food. I do not propose entering upon the breeding of Indian freshwater fishes here, as the subject would inordinately increase the length of this paper; I will therefore merely remark that certain marine forms deposit their ova in the rivers of the plains, that many species from the plains ascend hill-rivers and choose side-streams for their offspring, whilst most of the amphibious forms pass up small watercourses and there deposit their ova. In short, the direct aerial respiration of certain amphibious fishes is a provision to enable those forms to migrate through moist grass and muddy channels. Numerous examples are given in Sir E. Tennent's 'Ceylon' and elsewhere of migrations of these fishes.

It is evident that as soon as the rains set in we find nature revivified in the East; and with the vegetation animal life wakens up. Insects and Invertebrates appear; food that is suitable for fish begins to abound. In tanks during the hot months the smaller forms of fish have served for the nourishment of the large ones; but as the bivalves, univalves, and frogs make their appearance the fish evidently begin to change their diet. Thus it is that at the commencement of the rains fish become very excited; apparently dissatisfied with the localities they inhabit, they restlessly seek a change. This may be owing to the same instinct which causes the migration of marine fishes to the fresh waters; or a change in the state of the waters augments their appetite, and with such arises the necessity of seeking a place where food more abounds.

The second form of migration of fishes, or their suddenly appearing where they have not been previously observed and could scarcely have existed, is one which deserves attention; and of this we have two forms—(1) falling from the clouds, (2) appearing in the plains or elsewhere after heavy rains.

That fishes have been observed falling from the clouds has been

shown on such conclusive evidence that a recapitulation of instances appears to be superfluous.

Fishes have been observed in the East to fall from the clouds in a fresh or in a decomposed condition. With reference to this, it has been said that, sucked up by waterspouts, they may be carried long distances. Last year, on October 5th, it was observed in 'Nature' that "a tornado of almost unexampled intensity and destructiveness swept over the Isle of Wight . . . and extended at least 16 miles to the N.E. of Cowes . . . A gentleman in a small yacht, which fortunately was out of the course of the tornado, suddenly heard sounds very much resembling the noise caused by the escape of steam when at its highest pressure; and at the same time the whole sky became clouded with articles of all forms and sizes, which were carried through the air to a height of about 300 feet and parallel with the shore . . . Turnips and other crops were literally dragged out of the ground." This instance shows on a small scale what exists in the East, how articles may be sucked up, how little pools of water with the contained fish may be taken up in a whirlwind; and should the heat be excessive, one can easily imagine how soon these masses of animal substance might decompose. Every one in India has observed miniature whirlwinds sucking up the dust in an hour-glass form, and with it pieces of straw &c. which come within its influence.

The various accounts of fishes falling from the clouds may be classified as follows:—*first*, those descending during violent storms of winds and rain; *secondly*, appearing when no storm occurred. Amongst the first of these classes they have been recorded as distributed over some considerable extent of country in a continuous straight line, not more than a span in breadth, or else as covering a moderate-sized spot.

Of the second form it has always seemed to me to be an open question whether such were not fishes appearing suddenly in moist places where they had not been previously observed, and in a manner which I now propose to enter into.

I have seen large fish suddenly appear after heavy rains in most unlikely places—in fact, where but recently the locality had been a dry open plain; and I have since seen them dug out of the ground. I place these two instances together, as one may have a considerable bearing on the other. During the dry months of the year it is certain that almost every piece of water is stocked with fish; and at these periods the minute forms play a most

important part in providing for the nourishment of the larger kinds.

All species, amphibious or not so, it is asserted, may be found torpid; and John Hunter's hypothesis is probably correct. He observes "that hibernation is apparently due to a suspension of the faculties of animals by nature during such seasons and in such situations that a supply of food is not obtainable." Fish sleep or æstivate during the hot months at a period when nature is generally torpid, reviving again with the monsoon-rains as animal life resuscitates.

In Orissa the following instance occurred of the exhumation of fishes from the earth.

I was fishing there in January 1869, in company with a very intelligent native, to whom I expressed a wish to see fish exhumed from the mud of tanks. He remarked that those which I have termed amphibious, and also the spined eels, or Rhynchobdellidæ invariably retire into the mud of tanks as the water dries up; but he denied that carp ever did.

He suggested that we should at once make a trial at a neighbouring tank, which was about an acre in extent and had not more than four inches depth of water in its centre, whilst its circumference was sufficiently hardened to walk upon. The soil was a thick, consistent, bluish clay, and no excavation was made within thirty paces of the water.

Within five minutes the coolies extracted, from at least 2 feet below the mud, two *Ophiocephalus punctatus* and three *Rhynchobdella aculeata*, all of which were lively and not in the least torpid.

There is a specimen of *Amphipnous cuchia*, or the amphibious eel, in the Calcutta Museum, 13 inches long, presented by S. E. Peal, Esq., with the following label:—"This fish was hoed out of stiff blue clay as I was standing overlooking men at work making a bund, June 24th, 1865. No water had been seen near for some time"*.

We could easily suppose that what occurs in the *Lepidosiren* may likewise take place in these amphibious fishes. *Lepidosiren* are found inactive during the hot dry months, when their pulmonary air-bladders are employed for respiration; during this time of the year they burrow in the mud, which becomes dried above, them; but they maintain a small communicating aperture with the outer world, "and coiling themselves up in their cool chamber clothe themselves by a layer of thick mucous secretion, and await

* The remainder of the label illegible.

in a torpid state the return of the rains." Again in water, they swim about, use their branchiæ; and with an augmented arterial circulation their activity returns, appetite increases, and propagation commences.

Whether the Indian amphibious fishes likewise maintain an outlet to the atmosphere, I have not been able to ascertain; but that in some conditions eels do so is indisputable. Yarrell observes, respecting eels burying themselves, that the people of Somersetshire know how to find the holes in the banks of the rivers in which eels are laid up, by the hoar-frost not lying over them as it does elsewhere, and dig them out in heaps*.

Note on a new Example of the Phyllodocidæ (*Anaitis rosea*).

By W. C. M'Intosh, M.D., F.R.S.E., F.L.S.

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In the Catalogue of the Annelida in the British Museum the precise habitats of the Phyllodocidæ are very slightly alluded to. Thus, in regard to the common, though very beautiful, *Phyllodoce maculata*, Johnst., "Berwick Bay" is all the information afforded. At St. Andrews and other parts this species (which corresponds in colour and some other respects with the *P. citrina* of Malmgren) is very often found at the extreme margin of low water, several inches in the fine sand; and last autumn a single example of the new *Anaitis* occurred with it at the former locality.

The family Phyllodocidæ is at present a somewhat difficult one to study, because the bodies of the animals are both soft and friable, and lose many of their characters soon after preservation in spirit. Hence, in adopting Dr. Malmgren's generic title *Anaitis*, I concur with M. Claparède in doing so simply to avoid complication in synonymy.

The genus *Anaitis* is characterized by the fact that while the first three pairs of tentacular cirri are borne by the buccal segment, the fourth pair occur on the succeeding one; but much greater precision is yet required in this group.

Anaitis rosea is a small species, measuring about an inch and a half; but the tail is absent in the specimen. The head is pale ante-

* Although I have not personally seen any Cyprinidæ exhumed out of dried-up mud, still that such does occur in the East appears to be proved by sufficiently good authority. In fact, in Europe carps bury themselves in the mud, and pass months without eating, assembled in great numbers side by side.